



# RESEARCH MEMORANDUM

NORMAL ACCELERATIONS AND ASSOCIATED OPERATING CONDITIONS  
ON FOUR TYPES OF COMMERCIAL TRANSPORT AIRPLANES FROM  
VGH DATA AVAILABLE AS OF SEPTEMBER 1951

By Roy Steiner and Doris A. Persh

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NATIONAL ADVISORY COMMITTEE  
FOR AERONAUTICS

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Results obtained from time-history records (VGH records) of normal accelerations, airspeed, and altitude have been presented in references 1 to 3. Additional data have been obtained from the operations of two types of commercial transport airplanes reported in reference 3 together with data on two other types of transport airplanes. It is felt that a summary of the data from these four types of airplanes is of sufficient interest to airplane designers and operators to warrant issuance. The data, which were collected between January 1950 and September 1951 and include the data in reference 3, are summarized herein.

Pertinent characteristics of the four airplanes, designated A, B, C, and D, were obtained from the Civil Aeronautics Administration and the operators and are given in table I. Airplanes A and C were operated on a transcontinental route, whereas airplane B was operated on parts of a route from New York to Hawaii or Alaska via Seattle. Airplane D was operated on a north-south route in the eastern part of the United States.

The records covered about 377, 520, 377, and 118 hours of flight for airplanes A, B, C, and D, respectively, and represent operations to pressure altitudes of approximately 26,000, 26,000, 16,000, and 20,000 feet, respectively.

The evaluation of the time-history records was made essentially in accordance with the procedure outlined in reference 1. The altitude, however, was read as pressure altitude instead of altitude above terrain as in references 1 and 2. This change in the method of reading the records was made because it was not feasible to determine the altitude above terrain for the longer flights. The results are presented in tables II to V and are tabulated, for convenience, in altitude brackets of 5,000 feet. All flight distances are based on indicated airspeeds.

Since a sample of at least 1,000 hours is considered necessary to define trends for a given set of operations (reference 2), it is evident that no final conclusions should be drawn from the data. It may be noted

from the tables, however, that the total frequency of loads within an altitude bracket decreases rapidly with increasing altitude. To examine this trend further, the average number of acceleration increments  $\Delta n$  greater than  $\pm 0.3g$  per mile of flight is plotted against altitude in figure 1. As indicated in the figure, the number of acceleration increments per mile of flight decreases with increasing altitude up to about 17,000 feet. Above this altitude, the data from airplanes A and B indicate an increase in the number of loads; however, this increase does not appear to be significant, since airplane A only flew about 15 hours (4 percent of the time) at an altitude of 20,000 to 25,000 feet and airplane B only flew about 6 hours (1.5 percent of the time) at 25,000 to 30,000 feet. The increased load frequency may also be due in part to an attempt to fly above more turbulent conditions at the lower altitudes.

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#### REFERENCES

1. Steiner, Roy, and McDougal, Robert L.: Summary of Normal Accelerations, Gust Velocities, and Operating Practices From April to August 1949 of a Twin-Engine Airplane in Commercial Transport Operations. NACA RM L50B02, 1950.
2. Press, Harry, and McDougal, Robert L.: The Gust and Gust-Load Experience of a Twin-Engine Low-Altitude Transport Airplane in Operation on a Northern Transcontinental Route. NACA TN 2663, 1952.
3. McDougal, Robert L.: Summary of the First Sample of VGH Data of Normal Accelerations and Associated Operating Conditions on Two Four-Engine Transport Airplanes in Commercial Operations. NACA RM L50D28a, 1950.

TABLE I  
AIRPLANE CHARACTERISTICS

| Airplane | Span<br>(ft) | Wing area<br>(sq ft) | Gross<br>weight<br>(lb) | Design<br>maximum level-<br>flight speed<br>(indicated mph) |
|----------|--------------|----------------------|-------------------------|---|
| A        | 117.5        | 1463                 | 93,200                  | 279   |
| B        | 141.2        | 1720                 | 142,500                 | 312   |
| C        | 91.75        | 817                  | 40,500                  | 280   |
| D        | 123          | 1650                 | 107,000                 | 271   |



TABLE II  
SUMMARY OF VGE DATA FROM AIRPLANE A

(a) Gust loads and airspeed

| Flight condition | Flight distance (miles) | Average indicated airspeed (mph) |           | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Number of $\Delta n$ 's $\geq \pm 0.3g$ per mile of flight | Maximum $\Delta n$ (g units) |
|------------------|-------------------------|----------------------------------|-----------|---|--|------------------------------|
|                  |                         | Rough air                        | Total air |   |  |                              |
| Climb            | 7,879                   | 201                              | 194       | 94                                      | 0.0119   | 0.5 to 0.6                   |
| En route         | 61,636                  | 233                              | 233       | 272                                     | .0044  | .8 to .9                     |
| Descent          | 17,337                  | 239                              | 241       | 414                                     | .0239  | .7 to .8                     |
| Total            | 86,850                  | ---                              | ---       | 780                                     | -----  | -----                        |
| Average          | -----                   | 233                              | 230       | ---                                     | .0090  | -----                        |

(b) Gust loads experienced and percentage of flight miles by altitude brackets

| Altitude<br>Flight condition | 0 to 5,000 feet                         |                            |                              | 5,000 to 10,000 feet                    |                            |                              | 10,000 to 15,000 feet                   |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | 78                                      | 3.22                       | 0.5 to 0.6                   | 14                                      | 2.76                       | 0.4 to 0.5                   | 2                                       | 2.27                       | 0.3 to 0.4                   |
| En route                     | 59                                      | 4.90                       | .7 to .8                     | 82                                      | 9.39                       | .7 to .8                     | 85                                      | 21.22                      | .8 to .9                     |
| Descent                      | 360                                     | 8.32                       | .7 to .8                     | 44                                      | 5.98                       | .5 to .6                     | 9                                       | 3.89                       | .6 to .7                     |
| Total                        | 497                                     | 16.44                      | -----                        | 140                                     | 18.13                      | -----                        | 96                                      | 27.38                      | -----                        |

| Altitude<br>Flight condition | 15,000 to 20,000 feet                   |                            |                              | 20,000 to 25,000 feet                   |                            |                              | 25,000 to 30,000 feet                   |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | ---                                     | 0.72                       | -----                        | ---                                     | 0.10                       | -----                        | ---                                     | -----                      | ---                          |
| En route                     | 10                                      | 31.93                      | 0.4 to 0.5                   | 36                                      | 3.41                       | 0.5 to 0.6                   | ---                                     | 0.12                       | ---                          |
| Descent                      | ---                                     | 1.39                       | -----                        | 1                                       | .37                        | .3 to .4                     | ---                                     | .01                        | ---                          |
| Total                        | 10                                      | 34.04                      | -----                        | 37                                      | 3.88                       | -----                        | ---                                     | .13                        | ---                          |

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TABLE III  
SUMMARY OF VGH DATA FROM AIRPLANE B

(a) Gust loads and airspeed

| Flight condition | Flight distance (miles) | Average indicated airspeed (mph) |           | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Number of $\Delta n$ 's $\geq \pm 0.3g$ per mile of flight | Maximum $\Delta n$ (g units) |
|------------------|-------------------------|----------------------------------|-----------|---|--|------------------------------|
|                  |                         | Rough air                        | Total air |   |  |                              |
| Climb            | 13,252                  | 204                              | 195       | 201                                     | 0.0152   | 0.5 to 0.6                   |
| En route         | 79,306                  | 234                              | 223       | 364                                     | .0046  | .9 to 1.0                    |
| Descent          | 23,693                  | 238                              | 245       | 1758                                    | .0742  | .8 to .9                     |
| Total            | 116,251                 | ---                              | ---       | 2323                                    | -----  | -----                        |
| Average          | -----                   | 235                              | 224       | ----                                    | .0200  | -----                        |

(b) Gust loads experienced and percentage of flight miles by altitude bracket

| Altitude<br>Flight condition | 0 to 5,000 feet                         |                            |                              | 5,000 to 10,000 feet                    |                            |                              | 10,000 to 15,000 feet                   |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | 158                                     | 3.25                       | 0.5 to 0.6                   | 17                                      | 3.53                       | 0.5 to 0.6                   | 23                                      | 2.99                       | 0.5 to 0.6                   |
| En route                     | 51                                      | 1.24                       | .6 to .7                     | 163                                     | 8.39                       | .9 to 1.0                    | 51                                      | 20.94                      | .6 to .7                     |
| Descent                      | 1464                                    | 8.40                       | .8 to .9                     | 227                                     | 5.93                       | .7 to .8                     | 56                                      | 4.23                       | .6 to .7                     |
| Total                        | 1673                                    | 12.89                      | -----                        | 407                                     | 17.85                      | -----                        | 130                                     | 28.16                      | -----                        |

| Altitude<br>Flight condition | 15,000 to 20,000 feet                   |                            |                              | 20,000 to 25,000 feet                   |                            |                              | 25,000 to 30,000 feet                   |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | --                                      | 1.28                       | -----                        | 3                                       | 0.34                       | 0.3 to 0.4                   | --                                      | 0.01                       | -----                        |
| En route                     | 73                                      | 25.92                      | 0.6 to 0.7                   | 5                                       | 10.54                      | .3 to .4                     | 21                                      | 1.19                       | 0.5 to 0.6                   |
| Descent                      | 3                                       | 1.51                       | .4 to .5                     | 8                                       | .30                        | .5 to .6                     | --                                      | .01                        | -----                        |
| Total                        | 76                                      | 28.71                      | -----                        | 16                                      | 11.18                      | -----                        | 21                                      | 1.21                       | -----                        |



TABLE IV  
SUMMARY OF VGH DATA FROM AIRPLANE C

(a) Gust loads and airspeed

| Flight condition | Flight distance (miles) | Average indicated airspeed (mph) |           | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Number of $\Delta n$ 's $\geq \pm 0.3g$ per mile of flight | Maximum $\Delta n$ (g units) |
|------------------|-------------------------|----------------------------------|-----------|---|--|------------------------------|
|                  |                         | Rough air                        | Total air |   |  |                              |
| Climb            | 8,939                   | 182                              | 169       | 538                                     | 0.0602   | 0.7 to 0.8                   |
| En route         | 48,059                  | 202                              | 207       | 1570                                    | .0327  | .9 to 1.0                    |
| Descent          | 18,274                  | 196                              | 199       | 1647                                    | .0901  | 1.1 to 1.2                   |
| Total            | 75,272                  | ---                              | ---       | 3755                                    | -----  | -----                        |
| Average          | -----                   | 197                              | 199       | -----                                   | .0499  | -----                        |

(b) Gust loads experienced and percentage of flight miles by altitude bracket

| Altitude<br>Flight condition | 0 to 5,000 feet                         |                            |                              | 5,000 to 10,000 feet                    |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | 510                                     | 8.23                       | 0.7 to 0.8                   | 28                                      | 3.29                       | 0.5 to 0.6                   |
| En route                     | 759                                     | 18.36                      | .7 to .8                     | 753                                     | 35.69                      | .6 to .7                     |
| Descent                      | 1548                                    | 18.75                      | 1.1 to 1.2                   | 98                                      | 5.29                       | .8 to .9                     |
| Total                        | 2817                                    | 45.14                      | -----                        | 879                                     | 44.27                      | -----                        |

| Altitude<br>Flight condition | 10,000 to 15,000 feet                   |                            |                              | 15,000 to 20,000 feet                   |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | ---                                     | 0.34                       | -----                        | ---                                     | 0.02                       | -----                        |
| En route                     | 57                                      | 9.14                       | 0.9 to 1.0                   | 1                                       | .65                        | 0.3 to 0.4                   |
| Descent                      | 1                                       | .43                        | .3 to .4                     | ---                                     | .01                        | -----                        |
| Total                        | 58                                      | 9.91                       | -----                        | 1                                       | .68                        | -----                        |

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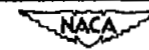
TABLE V  
SUMMARY OF VGH DATA FROM AIRPLANE D  
(a) Gust loads and airspeed

| Flight condition | Flight distance (miles) | Average indicated airspeed (mph) |           | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Number of $\Delta n$ 's $\geq \pm 0.3g$ per mile of flight | Maximum $\Delta n$ (g units) |
|------------------|-------------------------|----------------------------------|-----------|---|--|------------------------------|
|                  |                         | Rough air                        | Total air |   |  |                              |
| Climb            | 3,422                   | 193                              | 178       | 10                                      | 0.0029   | 0.7 to 0.8                   |
| En route         | 17,672                  | 213                              | 228       | 67                                      | .0038  | .8 to .9                     |
| Descent          | 5,172                   | 241                              | 241       | 97                                      | .0188  | .8 to .9                     |
| Total            | 26,266                  | ---                              | ---       | 174                                     | ---  | .8 to .9                     |
| Average          | ---                     | 227                              | 222       | ---                                     | .0066  | ---                          |

(b) Gust loads experienced and percentage of flight miles by altitude bracket

| Altitude<br>Flight condition | 0 to 5,000 feet                         |                            |                              | 5,000 to 10,000 feet                    |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | 1                                       | 5.07                       | 0.3 to 0.4                   | 9                                       | 4.25                       | 0.7 to 0.8                   |
| En route                     | 3                                       | 3.99                       | .6 to .7                     | 10                                      | 12.16                      | .8 to .9                     |
| Descent                      | 78                                      | 9.75                       | .8 to .9                     | 10                                      | 6.45                       | .4 to .5                     |
| Total                        | 82                                      | 18.81                      | ---                          | 29                                      | 22.86                      | ---                          |

| Altitude<br>Flight condition | 10,000 to 15,000 feet                   |                            |                              | 15,000 to 20,000 feet                   |                            |                              | 20,000 to 25,000 feet                   |                            |                              |
|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|---|----------------------------|------------------------------|
|                              | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) | Number of $\Delta n$ 's $\geq \pm 0.3g$ | Percent total flight miles | Maximum $\Delta n$ (g units) |
| Climb                        | ---                                     | 2.71                       | ---                          | ---                                     | 0.97                       | ---                          | ---                                     | 0.03                       | ---                          |
| En route                     | 48                                      | 31.19                      | 0.8 to 0.9                   | 5                                       | 17.21                      | 0.7 to 0.8                   | 1                                       | 2.73                       | 0.3 to 0.4                   |
| Descent                      | 9                                       | 2.69                       | .6 to .7                     | ---                                     | .78                        | ---                          | ---                                     | .02                        | ---                          |
| Total                        | 57                                      | 36.59                      | ---                          | 5                                       | 18.96                      | ---                          | 1                                       | 2.78                       | ---                          |





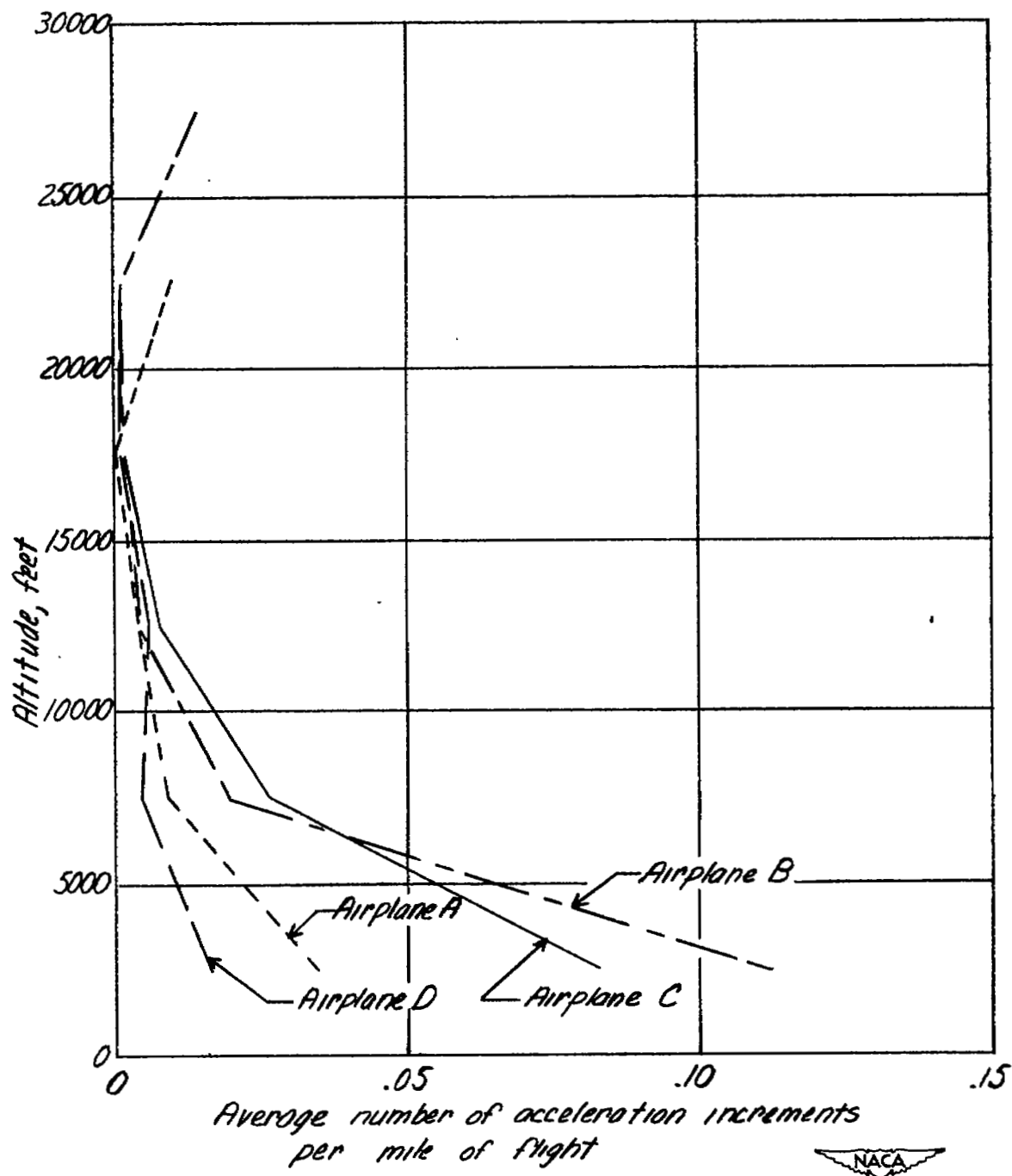


Figure 1.- Average number of acceleration increments equal to or greater than  $\pm 0.3g$  per mile of flight by airplane by altitude bracket.

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